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# TECHNOLOGY FOR PROCESSING COAL AND CONVERTING IT INTO AN ENERGY SOURCE BY EXTRACTING GAS

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**Abstract**

This study explores the suitability of beneficiated Uzbek coal as a feedstock for gasification and pyrolysis processes. XRF analysis of the unprocessed coal indicated a high concentration of inert, ash-producing minerals, while SEM imaging showed a compact structure with minimal porosity. GC–MS analysis of the resulting fuel confirmed the presence of key hydrocarbon components. Overall, the results indicate that treated coal offers high efficiency and low residue, making it well-suited for modern fuel conversion applications.

**Keywords:** *coal beneficiation, gasification, pyrolysis, XRF analysis, SEM imaging, GC–MS, synthetic gas, energy efficiency, carbon content, Uzbekistan coal*

## Introduction

Ensuring global energy security, reducing reliance on conventional fuels, and preserving environmental balance are among the most urgent scientific and practical challenges today (Li, F., & Fan, L.S., 2008). Coal gasification technology – used to convert coal into synthetic gas (CO, $H_2$, $CH_4$, and other components)—is becoming increasingly vital in the modern energy sector (Yusupov, F., & Khursandov, B., 2024). Leading countries by coal reserves include the United States (250 billion tons), China (143 billion tons), India (111 billion tons), Russia (160 billion tons), and South Africa (30 billion tons) (Miller, B. G., 2010). However, direct combustion of coal leads to substantial environmental pollution, especially through the emission of carbon dioxide ($CO_2$) (Miura, Kouichi, 2000), sulfur oxides ($SO_x$), and nitrogen oxides ($NO_x$), all of which significantly contribute to global warming and air quality deterioration (Kucharov, Azizbek, et al., 2025).

Consequently, scientific research is accelerating into coal conversion technologies such as pyrolysis and gasification, which aim to produce cleaner, high-efficiency synthetic gas. This gas not only improves fuel efficiency but also expands its industrial applications–serving as a feedstock for heat and power generation, as well as the synthesis of methanol, ammonia, hydrogen, and other chemical products (Xursandov, Bobomurod, et al., 2024). While advanced solutions like Clean Coal Technology and Integrated Gasification Combined Cycle (IGCC) have been deployed worldwide, there remain key unresolved challenges regarding their energy efficiency and economic feasibility under varying conditions (Kucharov, Azizbek, et al., 2021).

In Uzbekistan, domestic coal resources – such as Angren (1.9 billion tons), Shargun (45 million tons), and Boysun (36 million tons)—remain largely underutilized. Implementing coal gasification technologies tailored to local conditions can enhance national energy security, reduce dependence on imported energy, and mitigate environmental risks (Qurbonov, Azizjon, Azizbek Kucharov, and Farxod Yusupov, 2024). Therefore, developing the scientific foundations for synthetic gas production from coal and applying these methods at industrial scale is a highly relevant and strategic scientific goal for the country.

## Research method

Coal samples were collected from the [region] deposit. After drying at 105 °C and grinding below 100 µm, flotation was applied using an anionic surfactant to obtain an enriched coal fraction.

**XRF analysis** was performed to determine elemental composition using a Rh-anode XRF spectrometer under helium atmosphere. High levels of Si, Al, and Ca indicated inert, ash-forming compounds. Fe and S signaled the presence of pyrite, while trace Zn, Cu, Ag, Cd, Zr, and Rb reflected either geogenic or anthropogenic origins.

**SEM** imaging (500× magnification) was used to examine surface morphology before (Spectrum 29) and after enrichment (Spectrum 40). Untreated coal showed a dense, low-porosity structure with ~35% $SiO_2$ and 28% $Al_2O_3$. In contrast, enriched coal exhibited >25% porosity, reduced Si and Al (~10–12%), and increased carbon content (~65–70%).

**GC–MS analysis** of the synthesized fuel product was conducted using EI+ ionization and a 30 m capillary column. Major peaks at 4.79 min and 4–6 min confirmed volatile light fractions; heavier compounds appeared between 9–18 min, indicating a mixture of fuel-relevant and inert substances.

## Result and discussion

According to the results of the XRF analysis, the coal sample contains high levels of silicon (Si), aluminum (Al), and calcium (Ca), indicating a significant presence of inert, ash-forming components. The detection of iron (Fe) and sulfur (S) suggests the presence of pyrite and other iron sulfides, which can lead to the release of hydrogen sulfide ($H_2S$) during the gasification process.

Additionally, trace amounts of heavy metals such as Zn, Cu, Ag, and Cd were recorded, which may be related to anthropogenic contamination or background signals specific to the equipment (Figure 1). The presence of rare elements such as zirconium (Zr) and rubidium (Rb) indicates that the coal deposit has a geologically unique and distinctive composition.

According to the morphological and elemental analysis, the untreated coal sample (Figure 2a) has a smooth and dense structure with low porosity (porosity density < 10%). This is clearly visible in the SEM image. The high content of $SiO_2$ and $Al_2O_3$—approximately 35% and 28%, respectively – indicates the presence of ash-forming inert compounds. The carbon (C) content is around 30–35%, suggesting a low proportion of combustible fractions. This implies that the coal may not be an efficient fuel source for pyrolysis or gasification processes.

On the other hand, the enriched coal sample (Figure 2b) shows an increased number of microcracks and micropores on its surface (porosity density > 25%), which significantly increases the total surface area and enhances contact with reactive gases. Elemental analysis shows a reduction in Al and Si content to around 10–12%, indicating lower ash formation. The carbon content is approximately 65–70%, which greatly improves its energy yield. Thus, the enriched coal stands out in pyrolysis or gasification processes with higher efficiency, a high calorific value (around 25–28 MJ/kg), and a low residue rate (~5–8%). According to the chromatogram results, a prominent peak detected at 4.79 minutes in the analyzed organic substance indicates a high content of volatile, light fractions, suggesting good combustibility and energy release potential (**Figure 3**).

**Figure 1.** *XRF (X-ray fluorescence spectral analysis) image of the coal sample*

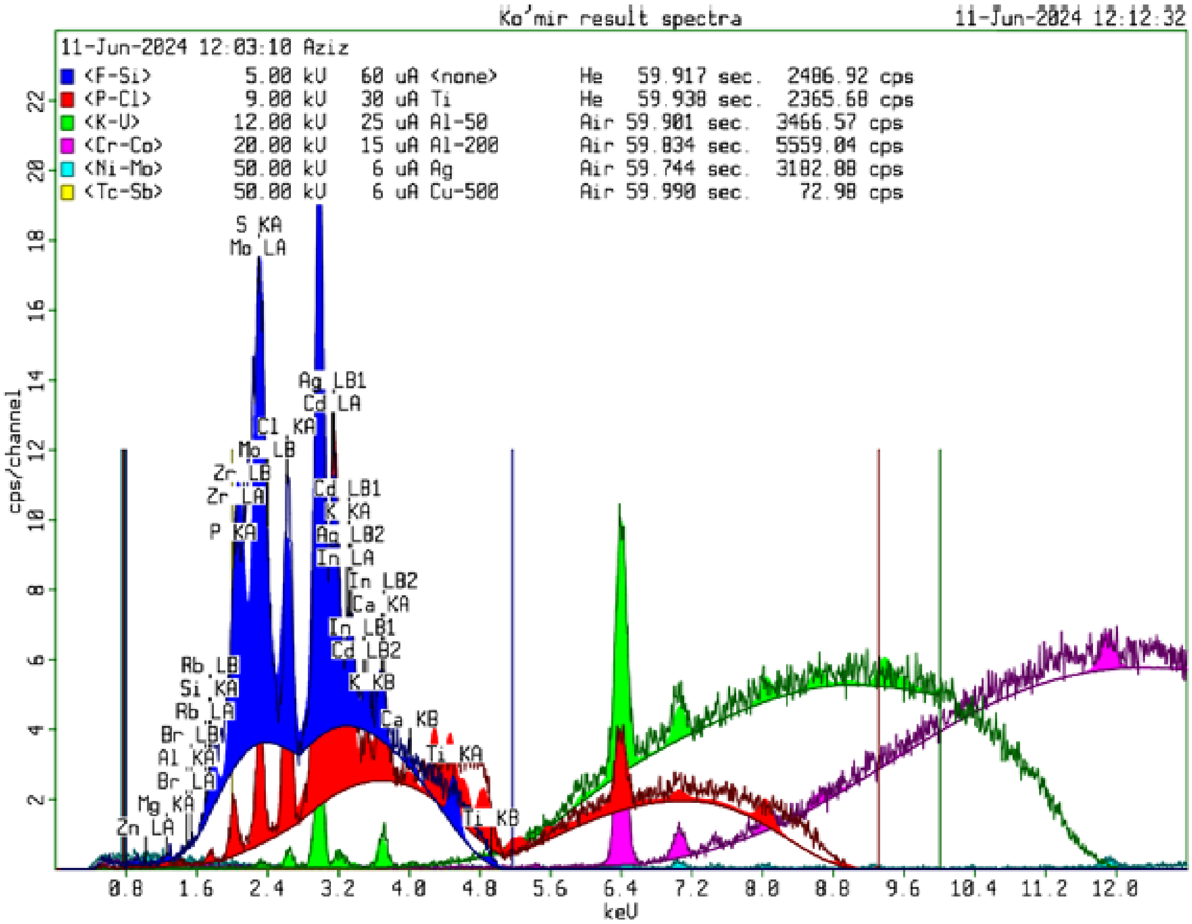



**Figure 2.** *SEM (Scanning Electron Microscope) images of the coal samples*

(a) before processing (b) after processing

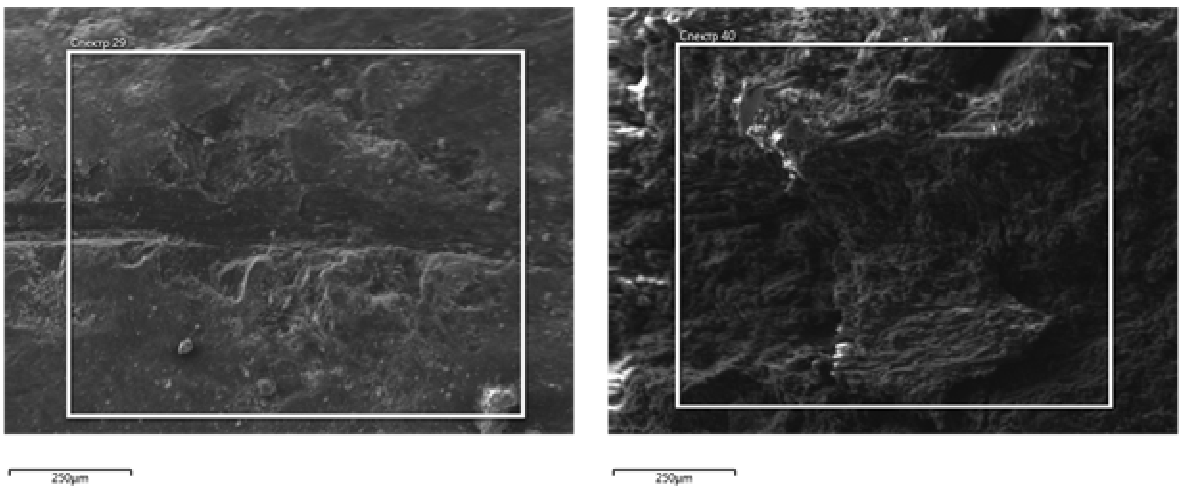
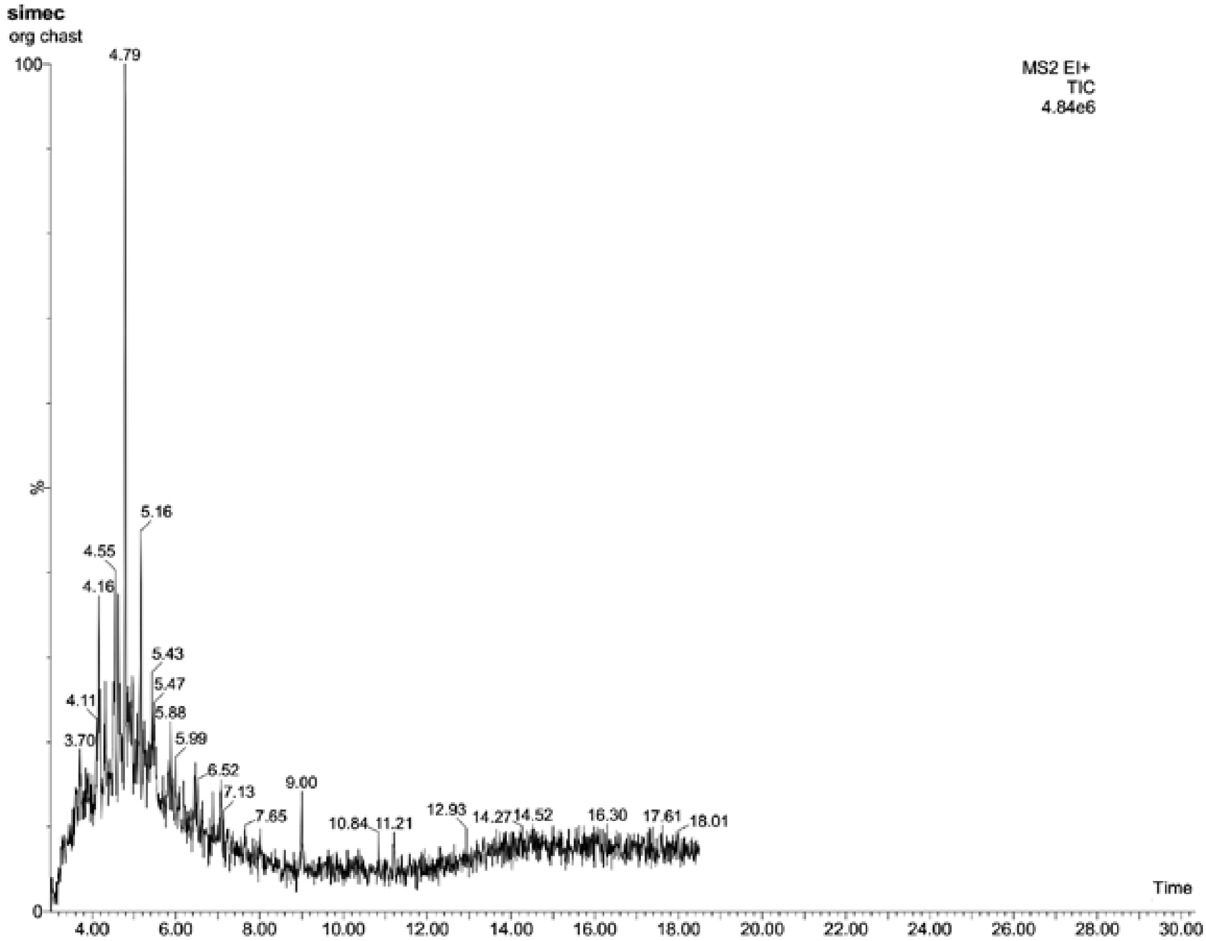


**Figure 3.** *"TIC (Total Ion Chromatogram) image of the synthesized fuel product obtained using GC–MS (Gas Chromatography–Mass Spectrometry)*




The strong peaks observed between 4–6 minutes point to components that could potentially be used as synthesis gas or light fuel. Between 9–18 minutes, heavier, higher molecular weight substances were identified; some of these are heat-resistant and may be useful as fuel, while others may require purification. After 18 minutes, the signal remains nearly constant, indicating the presence of inert residual substances.

## Conclusion

The experimental findings demonstrate that coal beneficiation significantly enhances its effectiveness as a feedstock for synthetic gas and liquid fuel production. XRF analysis showed that raw coal contains high levels of ash-forming minerals – around 35% $SiO_2$ and 28% $Al_2O_3$—along with calcium, iron, and sulfur, indicating substantial inert and pyritic content. In contrast, the enriched coal exhibited a reduced presence of Si and Al (~10–12%) and a marked increase in carbon content (approximately 65–70%), reflecting a twofold rise in combustible material. SEM analysis confirmed a shift from the smooth, low-porosity (<10%) surface of raw coal to a porous microstructure (>25%) in the treated sample, enabling better gas-solid interaction during thermal processes. GC–MS analysis further supported these results, identifying strong peaks at 4.79 and between 4–6 minutes – indicating the presence of light, volatile hydrocarbons ideal for clean combustion and syngas production – alongside heavier fractions between 9–18 minutes and minimal inert residue beyond 18 minutes. Overall, the upgraded coal offers higher calorific value (25–28 MJ/kg), reduced ash content (5–8%), and improved reactivity, making it a strong candidate for advanced, cleaner fuel technologies like gasification and pyrolysis.

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